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Technical Report

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Spreadsheet tools to estimate the thermal transmittance and thermal conductivities of gas spaces of an Insulated Glazing Unit

S.K. Nammi[a]., H. Shirvani[a]., A. Shirvani[a]., G. Edwards[b] and J. Dunn[c]

[a] Anglia Ruskin University, [b] University of Bolton, [c]Glazing Vision Ltd

Email: {Sathish.Nammi@anglia.ac.uk | Hassan.Shirvani@anglia.ac.uk | Ayoub.Shirvani@anglia.ac.uk | G.Edwards@bolton.ac.uk | Jeremy@glazingvision.co.uk}

Executive Summary

An Insulated Glazing unit (IGU) is constructed with two or more layers of glass panes sealed together by gas spaces in-between. IGUs are prevalent in windows, doors and rooflights, primarily due to their improved thermal resistance. Today, most IGUs are either two or three layered. Adding further layers of glass improves thermal insulation but with the penalty of increased cost and weight. Low emissivity (Low-e) film coatings, when deposited on the glass panes, reduce long-wavelength radiative heat losses. Furthermore, filling the gas spaces with the inert gases (e.g. Argon, Krypton, Xenon and SF6), further reduce conduction and natural convection across the gap. In summary, higher thermal insulation performance of an IGU can be achieved with gas fillings and Low-e coatings on glass. This report discusses spreadsheets that have been developed, capable of estimating the thermal transmittance values of IGU, as per BS EN 673. The spreadsheet tools also have the ability to estimate the thermal conductivity of the gas spaces between the panes of IGU.

Low Carbon KEEP

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Engineering Analysis, Simulation and Tribology (EAST) Research Group
Anglia Ruskin University
Bishop Hall Lane
Chelmsford
CM1 1SQ
UK
Tel: 08451963900

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1. Introduction

Windows, doors and rooflights are important in a building fabric. These are usually constructed by bonding a metal or wooden frame to an Insulated Glazing Unit (IGU). The IGU acts as a barrier between the indoor and outdoor environments. It stops wind and allows day light to enter. Many types of IGUs are constructed, with at least two or more panes of glass separated by a space and sealed with a spacer around their edges. There are many different kinds of spacers used in the fenestration industry. The spacer contains a desiccant (drying agent) which eliminates moisture vapour in the space (glazing cavity). Manufacturers often fill the glazing cavity with a mixture of air and an inert gas (e.g. Argon, Xenon and Krypton etc.). The combination of at least two panes of glass, separated by a hermetically sealed gas, acts as an efficient thermal barrier whilst offering the widest possible views, that connect the indoor spaces with the outdoors. A minimum of two panes of glass are necessary to construct a Double Glazing Unit (DGU) and three for Triple Glazing Unit (TGU). Increasing the number of layers of glass panes although improve the thermal insulation efficiency, at the same time increases the weight and size of unit. The vast majority of IGUs are constructed with either two or three glass panes, due to trades-offs between thermal insulation efficiency and IGU size/weight. Many IGU manufacturers add low radiation emissivity coating on selected glass panes. These coatings are highly transparent and do not greatly affect visible day light transfer. These coatings have a high reflectance to long-wavelength infrared radiation and reduce radiative heat transfer [1].

The thermal transmittance (widely referred to as U-value) parameter characterizes the heat transfer through the central part of glazing, under steady-state conditions, ignoring the edge effects. It is the heat flux rate per unit temperature difference between the indoor and outdoor environmental temperatures. The units of U-value are watts per square metre Kelvin $[W/(m^2.K)]$. The U-value parameter enables comparisons to be made between similar IGUs. The design standard EN 673 [2] specifies a calculation method, to determine the U-value of glazing with flat and parallel surfaces. The same standard also provides the calculation rules for the thermal conductance (λ) of gas spaces in multi-pane IGUs. The parameter λ is a necessary input to calculate the overall product U-value and the heat flows of a fenestration unit. The EN 673 standard applies to the glazing units constructed with both uncoated or coated glass and materials not transparent in the far infrared (e.g. soda lime, borosilicate glass and glass-ceramic etc.). It should be noted that this standard does not cover infrared transparent multiple glazing units, commonly sealed with gas space sheets or foils.

2. Spreadsheet tool

The authors of this report have developed spreadsheet tools to calculate the thermal conductivities (λ) of gas spaces between panes and centre-pane U-value of Insulated Glazing Unit (IGU). The spreadsheets DGU.xlsm and TGU.xlsm are for IGU constructed with two and three glass panes respectively. The algorithm in BS 673 [2] was implemented to estimate the aforementioned parameters. This spreadsheet tool takes as inputs the glass pane thickness and its orientation (either vertical or horizontal), gas spacing thickness and type of gas filling. The U-value for an IGU is sensitive to principal heat flow direction. The spreadsheet tool has been designed only for vertical and horizontal orientations of glazing encountered in practice. An illustration of the inputs (glass pane, gas type and space thickness) and calculated results (U value) of spreadsheets is shown in Figure 1 and Figure 2 for two and three pane IGUs respectively.

The results from the developed spreadsheet tool have been compared with existing results in the ISO standards to check the spreadsheet implementation. The centre-pane U-value results in Table C.2 of ISO 10077-1 [3] and thermal parameters in Table A.1 of BS 673 [2] were used as a benchmark. In Table 1 and Table 2, the calculated results from spreadsheets DGU.xlsm and TGU.xlsm are compared with the specified results in Table C.2 of ISO 10077-1, showing consistency, thus confirming that the spreadsheet implementation is correct. In Table 3, the thermal parameters described in in Table A.1 of BS 673 were compared with spreadsheet TGU.xlsm results and the results quoted in the standard and the spreadsheets are again in agreement.

3. Closure

Two spreadsheet (Viz: DGU.xlsm and TGU.xlsm) tools have been developed, which are reported here, to calculate centre-pane U-values and thermal conductivities of gas spaces of an IGU. It is anticipated that the availability of these calculation tools will be valuable in fenestration technology choice decision making, and also to promote low carbon economy.

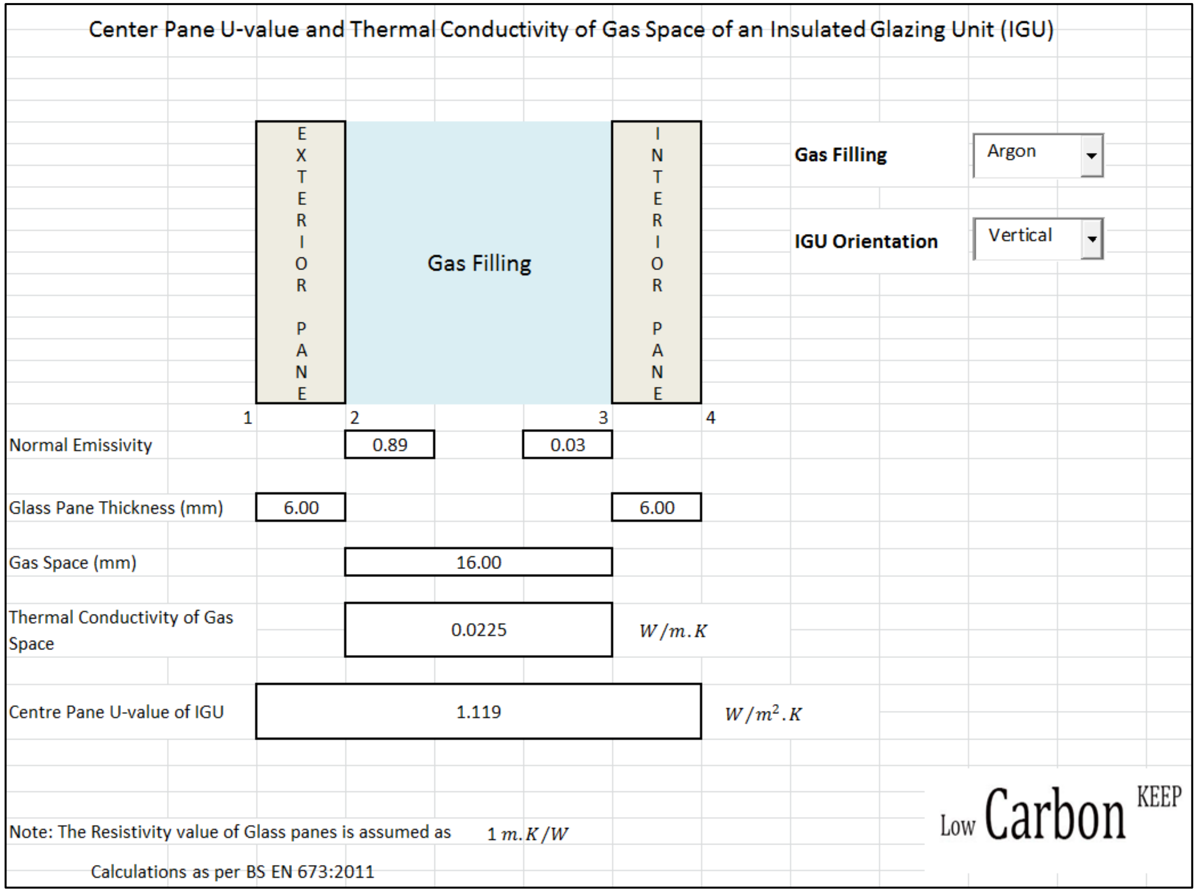

Figure 1: Spreadsheet tool for Double Glazing Unit (DGU.xlsm) with inputs**** and calculating outputs****

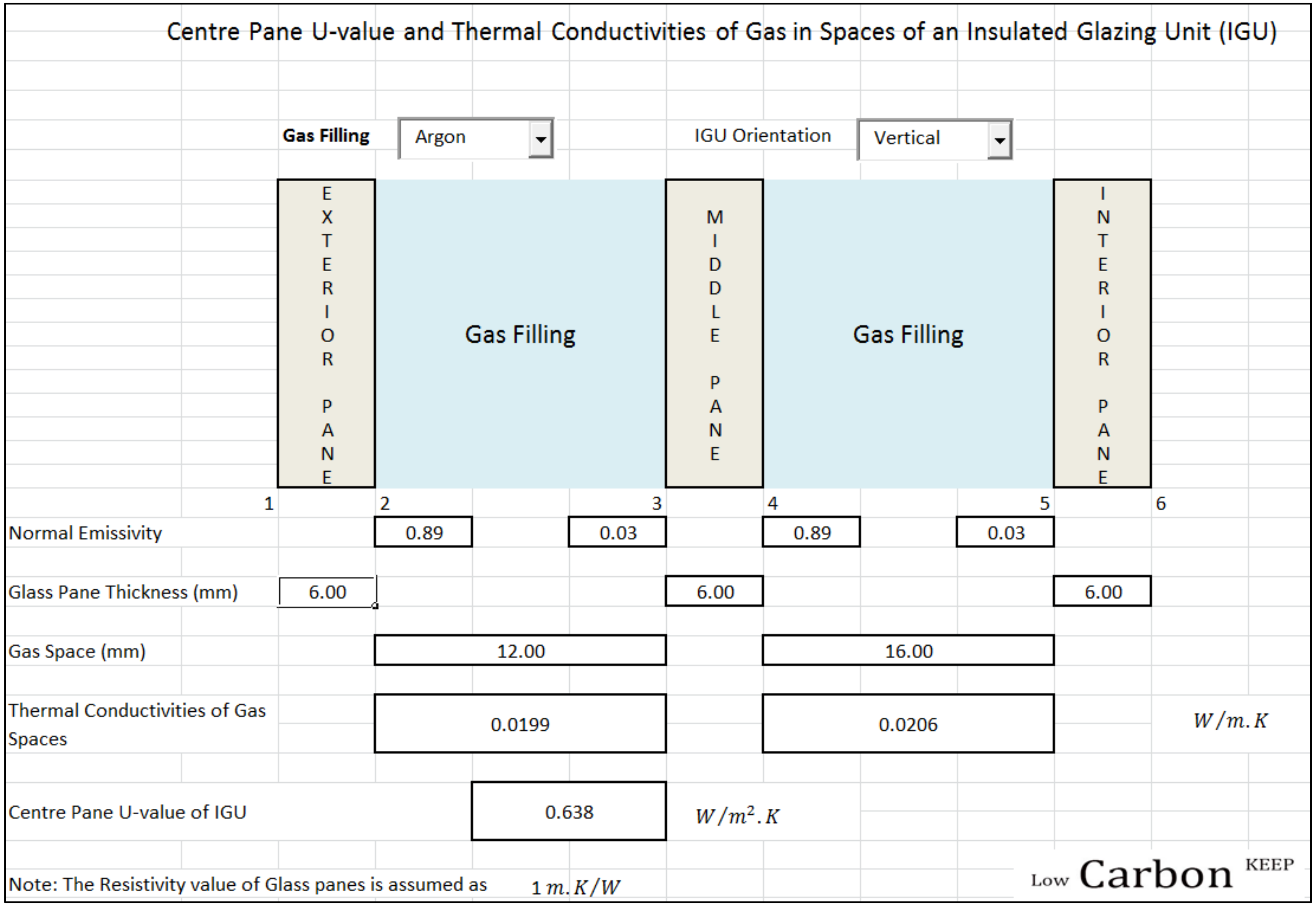

Figure 2: Spreadsheet tool for Triple Glazing Unit (TGU.xlsm) with inputs**** and calculating outputs****

Glazing				Thermal transmittance for different types of gas space $W/m^2.K$									
Type	Glass	Normal emissivity	Dimensions mm	Air		Argon		Krypton		SF6		Xenon	
				ISO 10077-1	DGU.xlsm result	ISO 10077-1	DGU.xlsm result	ISO 10077-1	DGU.xlsm result	ISO 10077-1	DGU.xlsm result	ISO 10077-1	DGU.xlsm result
Double glazing	Uncoated normal glass	0.89	4-6-4	3.3	**3.276**	3.0	**3.043**	2.8	**2.770**	3.0	**3.034**	2.6	**2.619**
			4-8-4	3.1	**3.080**	2.9	**2.878**	2.7	**2.651**	3.1	**3.058**	2.6	**2.589**
			4-12-4	2.8	**2.848**	2.7	**2.692**	2.6	**2.595**	3.1	**3.095**	2.6	**2.607**
			4-16-4	2.7	**2.730**	2.6	**2.621**	2.6	**2.609**	3.1	**3.121**	2.6	**2.621**
			4-20-4	2.7	**2.743**	2.6	**2.632**	2.6	**2.619**	3.1	**3.141**	2.6	**2.632**
	One pane coated glass	≤0.2	4-6-4	2.7	**2.712**	2.3	**2.345**	1.9	**1.891**	2.3	**2.330**	1.6	**1.629**
			4-8-4	2.4	**2.405**	2.1	**2.075**	1.7	**1.686**	2.4	**2.371**	1.6	**1.575**
			4-12-4	2.0	**2.024**	1.8	**1.756**	1.6	**1.587**	2.4	**2.428**	1.6	**1.608**
			4-16-4	1.8	**1.823**	1.6	**1.633**	1.6	**1.611**	2.5	**2.470**	1.6	**1.632**
			4-20-4	1.8	**1.846**	1.7	**1.653**	1.6	**1.630**	2.5	**2.503**	1.7	**1.652**
	One pane coated glass	≤0.15	4-6-4	2.6	**2.643**	2.3	**2.257**	1.8	**1.776**	2.2	**2.241**	1.5	**1.497**
			4-8-4	2.3	**2.320**	2.0	**1.972**	1.6	**1.558**	2.3	**2.284**	1.4	**1.439**
			4-12-4	1.9	**1.918**	1.6	**1.633**	1.5	**1.452**	2.3	**2.345**	1.5	**1.475**
			4-16-4	1.7	**1.703**	1.5	**1.502**	1.5	**1.478**	2.4	**2.389**	1.5	**1.501**
			4-20-4	1.7	**1.728**	1.5	**1.522**	1.5	**1.498**	2.4	**2.423**	1.5	**1.521**
	One pane coated glass	≤0.1	4-6-4	2.6	**2.569**	2.2	**2.162**	1.7	**1.652**	2.1	**2.145**	1.4	**1.353**
			4-8-4	2.2	**2.228**	1.9	**1.860**	1.4	**1.419**	2.2	**2.190**	1.3	**1.292**
			4-12-4	1.8	**1.802**	1.5	**1.499**	1.3	**1.306**	2.3	**2.255**	1.3	**1.329**
			4-16-4	1.6	**1.574**	1.4	**1.358**	1.3	**1.333**	2.3	**2.301**	1.4	**1.357**
			4-20-4	1.6	**1.600**	1.4	**1.381**	1.4	**1.354**	2.3	**2.337**	1.4	**1.379**
	One pane coated glass	≤0.05	4-6-4	2.5	**2.486**	2.1	**2.056**	1.5	**1.510**	2.0	**2.038**	1.2	**1.190**
			4-8-4	2.1	**2.126**	1.7	**1.733**	1.3	**1.260**	2.1	**2.085**	1.1	**1.123**
			4-12-4	1.7	**1.672**	1.3	**1.346**	1.1	**1.138**	2.1	**2.154**	1.2	**1.164**
			4-16-4	1.4	**1.427**	1.2	**1.195**	1.2	**1.168**	2.2	**2.203**	1.2	**1.194**
			4-20-4	1.5	**1.456**	1.2	**1.219**	1.2	**1.191**	2.2	**2.241**	1.2	**1.218**

Table 1: Comparison of DGU.xlsm tool and ISO 10077-1 results demonstrating consistency

Glazing				Thermal transmittance for different types of gas space $W/m^2.K$									
Type	Glass	Normal emissivity	Dimensions mm	Air		Argon		Krypton		SF6		Xenon	
				ISO 10077-1	TGU.xlsm result	ISO 10077-1	TGU.xlsm result	ISO 10077-1	TGU.xlsm result	ISO 10077-1	TGU.xlsm result	ISO 10077-1	TGU.xlsm result
Triple glazing	Uncoated normal glass	0.89	4-6-4-6-4	2.3	**2.291**	2.1	**2.069**	1.8	**1.824**	1.9	**1.946**	1.7	**1.696**
			4-8-4-8-4	2.1	**2.103**	1.9	**1.920**	1.7	**1.723**	1.9	**1.944**	1.6	**1.622**
			4-12-4-12-4	1.9	**1.893**	1.8	**1.757**	1.6	**1.616**	2.0	**1.972**	1.6	**1.620**
	Two panes coated	≤0.2	4-6-4-6-4	1.8	**1.775**	1.5	**1.473**	1.1	**1.132**	1.3	**1.302**	0.9	**0.949**
			4-8-4-8-4	1.5	**1.520**	1.3	**1.266**	1.0	**0.988**	1.3	**1.299**	0.8	**0.843**
			4-12-4-12-4	1.2	**1.228**	1.0	**1.037**	0.8	**0.834**	1.3	**1.338**	0.8	**0.840**
	Two panes coated	≤0.15	4-6-4-6-4	1.7	**1.716**	1.4	**1.404**	1.1	**1.050**	1.2	**1.227**	0.9	**0.861**
			4-8-4-8-4	1.5	**1.453**	1.2	**1.190**	0.9	**0.901**	1.2	**1.224**	0.8	**0.750**
			4-12-4-12-4	1.2	**1.151**	1.0	**0.952**	0.7	**0.741**	1.3	**1.264**	0.7	**0.747**
	Two panes coated	≤0.1	4-6-4-6-4	1.7	**1.654**	1.3	**1.332**	1.0	**0.964**	1.1	**1.148**	0.8	**0.767**
			4-8-4-8-4	1.4	**1.382**	1.1	**1.109**	0.8	**0.809**	1.1	**1.145**	0.7	**0.652**
			4-12-4-12-4	1.1	**1.069**	0.9	**0.862**	0.6	**0.643**	1.2	**1.187**	0.6	**0.649**
	Two panes coated	≤0.05	4-6-4-6-4	1.6	**1.619**	1.2	**1.290**	0.9	**0.914**	1.1	**1.102**	0.7	**0.712**
			4-8-4-8-4	1.3	**1.342**	1.0	**1.063**	0.7	**0.755**	1.1	**1.100**	0.5	**0.593**
			4-12-4-12-4	1.0	**1.021**	0.8	**0.809**	0.5	**0.587**	1.1	**1.143**	0.5	**0.591**

Table 2: Comparison of TGU.xlsm tool and ISO 10077-1 results demonstrating consistency

Parameter	Iteration number							
	1		2		3		4	
	EN 673	TGU.xlsm result	EN 673	TGU.xlsm result	EN 673	TGU.xlsm result	EN 673	TGU.xlsm result
$1/h_s$ for space 1 $[m^2.K/W]$	0.1934	**0.1935**	0.1934	**0.1935**	0.1934	**0.1935**	0.1934	**0.1935**
$1/h_s$ for space 2 $[m^2.K/W]$	0.7739	**0.7655**	0.7644	**0.7661**	0.7650	**0.7661**	0.7649	**0.7661**
$\sum_{1}^{2} 1/h_s$ $[m^2.K/W]$	0.9673	**0.9590**	0.9578	**0.9597**	0.9584	**0.9596**	0.9584	**0.9596**
ΔT for space 1 $[K]$	2.9990	**2.997**	3.0289	**3.027**	3.0270	**3.025**	3.0271	**3.025**
ΔT for space 2 $[K]$	12.0010	**12.003**	11.9711	**11.973**	11.9730	**11.975**	11.9729	**11.975**
U value $[W/m^2.K]$	0.870	**0.8764**	0.877	**0.8759**	0.877	**0.8759**	0.877	**0.8759**

Table 3: Comparison of TGU.xlsm calculated and thermal parameter results in ISO 673 results demonstrating consistency

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